# Statistical

# Consultation on

# CONCADE Project in

# Bolivia

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# STATISTICAL CONSULTATION ON CONCADE PROJECT IN BOLIVIA

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**December 5-14, 1999 and January 31 - February 12, 2000**

## EXECUTIVE SUMMARY

Approximately two weeks were spent at the IBTA La Jota Experimental Station in the Chapare in statistical consultations with researchers from various specialties, in giving a seminar on experimental design, and in teaching a three-day short course on the use of the SAS statistical package. The consultations gave me an overview of the technical problems being studied by the researchers and how they are approaching them. Also, I got a reading on the experimental design and research techniques being used in the field. During the December 1999 work in the Chapare, I visited a number of research plots in the field. In February, 2000 the statistical consulting work was done in the offices and laboratories of the researchers at the La Jota Station. I dealt with experiments and field trials in all of the major five alternative crops and the key staff of the experiment station investigating these crops. Treatments varied from fertility studies in soils to integrated pest management (IPM) interventions. To the latter was devoted considerable time since there are many different kinds of sampling and design problems which need to be studied in this area and some of them are rather difficult with which to deal. My conclusion for IPM is that each case is going to be different so one cannot set forth a set of recipes for the design of these experiments. We must create a network of individuals (extensionists and researchers) who learn how to diagnose a problem and then report it to a central place (IBTA, La Jota). Vigilance must be constant as the pests come and go even within one growing season. Surveys and experiments can then be designed to confirm the diagnosis

and to compare different methods of dealing with the problem. Forming the network is probably a key to research in IPM.

One of my goals throughout the work in the Chapare (including the SAS course) was to emphasize a quantitative approach to research. Whatever is recommended to farmers by extension personnel should be backed up by sound research by station staff. This implies that some full fledged, well-designed and replicated experiments are needed. The data from the experiments must be analyzed and interpreted correctly. There should be a thorough review of the literature from other places where similar studies have been conducted before embarking on an experiment. In some cases, this will obviate the need for a new experiment. In other cases, this will allow a clearer perception of the problem at hand and the objectives of the experiment. Some of the problems that occur in experimentation result from a confusion of the problem and diffuse objectives. This is a general problem, which is experienced all over the world by researchers. But time spent on researching unimportant topics is very valuable time and the use of limited resources on dead-end problems is also a waste.

One problem, which continually arises, is the amount of land available for an experiment because many of the La Jota sponsored experiments and validation trials are conducted on farmers' fields. I was told a number of times that there wasn't enough space for a full-fledged experiment so unreplicated trials were being used. Considerably more consulting work in the area of experimental design needs to be done with the researchers to explain the differences between experiments, validation trials and demonstration trials. The research staff on the station is quite interested in this topic so further work should be of interest to a number of workers. The principal point here is that researchers should set their expectations in accordance with the type of experiment or trial being carried out. (In other words, they shouldn't be expecting highly precise results from a demonstrational trial). The other point is that resources can be reallocated in many cases so that fewer plants are taken per plot and more replications can therefore be used. Once it is known

what needs to be done to achieve adequate precision, researchers are usually resourceful in optimizing the allocation of experimental resources.

In addition to problems with the size of experiment, there seems to be confusion as to what constitutes replication. Some researchers (especially in banana investigations) are using plant to plant variation within plots for an estimate of experimental error. This practice needs to be replaced by replication of the entire experimental plot because it results in an underestimate of experimental error (and consequently, too many significances in testing differences among treatments).

I presented a seminar on Experimental Design and Applied Statistics to station staff during my work at La Jota in December, 1999 and a three-day short course in the use of the statistical package (SAS) during my work there in February, 2000. During both of these presentations, I detected considerable interest in these topics and enthusiasm for more training in these areas. Consequently, I am recommending a one or two week short course in Experimental Design in late spring or early summer of 2000. I am recommending the purchase and installation of two more copies of SAS on computers at La Jota and subsequently, informal short courses on the use of SAS periodically in the future. Training in the design principles should come first, however, so that the researchers will know which SAS commands to use when analyzing data and the limitations of the package.

THROUGHOUT ALL OF THESE STEPS, RESEARCHERS SHOULD BE TRAINED IN RESEARCH PRINCIPLES AND THE NEED FOR QUANTITATIVE INVESTIGATIONS. IMPROVEMENT IN QUALITY OF RESEARCH OVER TIME SHOULD BE EXPECTED AND MONITORING CARRIED OUT TO BE SURE THAT THIS HAPPENS. IMPROVEMENT IN THE PRECISION OF EXPERIMENTS SHOULD BE CARRIED OUT SIMULTANEOUSLY WITH IMPROVEMENT IN SELECTION OF THE PRIORITY RESEARCH TOPICS.

## ACRONYMS

CONCADE = Counter Narcotics Consolidation of Alternative Development Efforts

COP = Chief of Party

DAI = Development Alternatives, Inc.

GOB = Government of Bolivia

IBTA = Instituto Boliviano de Technologia Agropecuaria Proyecto

IPM = Integrated Pest Management

LOE = Level of Effort

MIP = Integrated Pest Management

NCSU = North Carolina State University

SAS = Statistical Analysis System

STTA = Short Term Technical Assistant

USAID = U.S. Agency for International Development

## WORK IN THE CHAPARE (December 7- 12, 1999, January 31-February 12, 2000).

### INTERACTION WITH SHORT-TERM CONSULTANTS

I attended all of the talks given by the CONCADE - NCSU consultants during the December period. In addition, I tried to obtain some feedback from the Bolivian scientists at La Jota Experiment Station concerning these consultancies. One comment, which was heard more than once, was that the consultants came to La Jota without much warning and they were not used very effectively from a time standpoint. Since we are early into the project, this can be changed. In fact, steps have already been taken to improve the situation and the improvement is noticeable. Both DAI and NCSU have developed information sheets to guide the consultants as to what is expected of them and the conditions of their employment and travel particulars. A standard format for the trip report and schedule for submission has been developed to improve the final reports. DAI has developed a calendar for the work schedules in the Chapare with the coordination of other agencies working on CONCADE Project Chapare and this should improve the timing of the consultancies. Entry and exit interviews with the COP and other interested administrative individuals are now required of each consultant. These steps are welcomed as they should bring a better focus to the consultancies and make the consultants more efficient.

### FIELD OBSERVATIONS

My observations in the Chapare confirmed what I have seen in the past in tropical areas. Tropical soils are quite variable and the entire environment in the tropics lends more variability to the research setting. Add the lack of homogeneity of the plant materials being used in the experiments (plants within a plot) to the variability of soils, and one has

a real challenge to design experiments that will provide the needed precision. We can't afford to have additional variability caused by a human factor. This can be prevented by proper training of researchers and their assistants in the careful control at the experimental site.

I visited plots representing experiments on the five major crops. The purpose of these visits was to get an idea of the experimental design or demonstrational trial practices being used and to observe the growing habits of these crops. Mr. Yuri Maldonado and Mr. Andres Quiroga accompanied me on the visits to the fields of most crops, but on banana, Mr. Andres Quiroga and Mr. Rolando Escobar accompanied me. Most of the experiments were on farmers' fields but there were some on community-held property.

Observations made were of uniformity of the planting material, number of plants per plot, size and shape of plots, blocking procedures, randomization, etc. The experiments and demonstrations that I saw were fairly simple and small (few treatments and few replications). Only one or two of the experiments that I saw would have the power to detect reasonably sized differences. The experimental technique appears to be adequate in most cases, but if improvements in precision could be made, there would be more information from the experiments. The coefficients of variation quoted were something between 15 and 20 per cent, values that for some crops would be considered high. I gave some suggestions about how to obtain more precision on palmito experiments by using the number of tillers per plant as a covariable (the covariable could be expressed as number of tillers per plot). This is what is called statistical control as compared with local control (blocking).

Care should be taken to select uniform plants when forming plots. In some of the experiments, it appeared that there was a good deal of genetic variation among plants. This should be avoided but if that is difficult, larger plots are called for (averaging over a number of plants).

Concerning plot size, some experimentation with plot sizes for different crops needs to be conducted over time. One can benefit from an experiment in one year in planning the plot size of future experiments. Plot size does affect the precision of an experiment but mechanical considerations also play a role in deciding optimum plot size.

Design compromises are sometimes needed for the crops having large plants (e. g. banana). This is because the control treatment may infect the other chemically treated plots by spore drift, or even the chemical treatment itself may drift from one plot to another. This would suggest separation of plots and/or blocks by distance or using systematic arrangement of treatments to some extent in the blocks. This goes against the accepted principle of the use of compact blocks and also that of complete randomization. These compromises should not be made when dealing with crops having smaller plots, and should only be used when all else fails when designing experiments with crops having large plots.

A pineapple fertilizer experiment, in which the drought in the Chapare has influenced greatly the production of the second crop, was visited. I recommended proceeding to harvest the crop, realizing that the interpretation may not apply for making recommendations for a normal year. However, the results may be useful for determining which combination levels of added nutrients are most resistant to drought on that particular soil in the Chapare.

It seems that those responsible for designing experiments on and off of the La Jota Experiment Station need more outside help. The design textbooks are not adequate to cover the unique situations encountered in a crop like banana. One has to learn the principles and then they can be applied to a variety of situations. The station staff members need to work with design experts who can go to the field with them and critique their existing experiments or design new ones. The statistics section needs

training in the form of two more copies of the statistical package (SAS), and a small library including books dealing with Experimental Design and Methodology and statistical software manuals. Preferably these should be written in Spanish. For example, both Cochran and Cox and Steel and Torrie (classic design and methods texts) have Spanish translations. I personally will take on this challenge in the years that NCSU has the CONCADE Subcontract as the project administration requires me to travel to Bolivia.

In addition to purely statistical aspects, there were some general observations, which I made about the research efforts. One is that more effort needs to be made to clarify the objectives of the experiments and to make sure that the treatments chosen have a bearing on the problem at hand. One entomological experiment discussed had potential interference problems between adjacent plots but it turned out that the pheramones which were to be included in the experiment were specific to given insects. Once the objectives of the experiment and the mechanisms involved were clear, there was no need to be concerned about the plot interference problem because the different pheromones were specific for different insects and shouldn't have been included together in the same experiment.

The extension and research staffs working in the Chapare should be trained to be on the lookout for potential problems which impose constraints on production or quality and bring these to the attention of the La Jota Station research staff. If the station researchers need help in setting up experiments which will bear upon important field problems, they should seek outside help from some of the experts who have been working on the project in the Chapare. This applies to the Statistician as well as the biological researchers. But the point is, researchable problems should be brought to the attention of station staff by those close to the field who are trained to spot these problems.

Another issue uncovered did not deal with experimental design, but rather with treatment design. On a fertilizer experiment on pineapple, the weight of leaves responded to added

nitrogen in a linear fashion suggesting that perhaps the range of rates of nitrogen application was somewhat low. Future analyses of the fruit weight data should provide more information as to whether the response to nitrogen was linear for this variable also, and if so there would be a confirmation that the range in fertilizer rates was too low. Selecting appropriate ranges of quantitative treatment inputs and their spacings is quite important in experiments of this type because the estimation of the optimal rate of fertilizer requires a curvilinear response pattern. If the rates are too low, the curve is not achieved in the region of the treatment range.

The question of blocking in laboratory experiments in the Biotechnology Laboratory arose. If there is a chance or suggestion that the experimental area is not homogeneous, blocking should be carried out (even in a greenhouse, growth chamber, or laboratory). The principle of blocking may be used in any experimental situation in which more control of variation is important. One doesn't know for sure in advance if blocking will ultimately be necessary and beneficial, but the cost of blocking is low and the potential benefits (if it turns out to be needed) are large.

Size of experiments is an area, which needs some thinking and evaluation. Care should be taken to assure that experiments (or validation trials) are large enough to achieve the precision goals needed. If there are only a few treatments and a few replications, the degrees of freedom for estimating experimental error will be less that ten (which is considered to be the minimum). This can be improved by increasing the number of replications and/or treatments. There are some indications that on some experiments (and validation trials) too much effort is being expended because the number of plants per plot or observations during the growing season is excessive. To obtain a good picture of a process, one doesn't need hundreds or thousands of observations. The proper size can be arrived at by considering variation as well as cost per unit at each stage of the process. In some cases, one needs several plants per plot to stabilize the average over the plot or to make sure that some plants remain if mortality is an issue. But, if reduction of number of plants per plot results in considerable cost reduction and yet precision of the experiment

is not sacrificed, one should reduce the number. I recommended increased number of plants in some of the Biotechnologia Laboratorio experiments because the number of observations having a positive effect were being counted (as opposed to the number having a negative effect). On binomial count data such as these, a minimum of ten repetitions per plot was considered necessary in the laboratory because this will result in a much lower variance than in situations in which fewer plants per plot are available to be counted.

In some cases, letting the data speak through analysis is helpful. Interplot interference in a banana experiment was anticipated by Benigno Ocampo and Vincente Eguez but through analysis of variance, it was demonstrated that the problem was not as serious as expected and that further observations could be taken from the plots over time.

**PRESENTATION OF SEMINAR ON EXPERIMENTAL DESIGN AND STATISTICAL METHODS AT LA JOTA STATION**

On Sunday, December 12, 1999, I presented a lecture on Experimental Design and Statistical Methods to the staff of La Jota Station. Emphasis was on design principles for field experiments and methods of improving precision of experiments. The fact that small experiments in the field often do not have enough power to detect differences was pointed out. The components of variability in field experiments and approaches for reducing their magnitude were discussed. Considerable focus was placed on the difference between an experiment and a demonstration trial. An extended discussion ensued, much of which focussed on the distinction between experiments and demonstration trials and how these two different methods of research and extension might be utilized in the CONCADE Project. The staff seemed interested in Experimental Design and how it might be applied to the La Jota Experiment Station investigations. This also seems to be a priority of the administration of the La Jota Station.

It is recommended that a more intensive experimental design short course be presented at La Jota Station and that it go into more detail about design principles. This should be done in the late spring or early summer of 2000. The personnel of the station are hungry for this information and for that reason, it seems likely that they will put the information to good use. The format which I have found to be quite successful is to present lectures each morning and labs in the afternoon. In the afternoon labs, data sets dealing with the topics discussed in the experimental design portions in the morning, are analyzed on the computer. This allows the participants to better understand the design principles as well as to get some useful practical information on the use of the computer package such as SAS. The instructor of the course can then help the participants interpret the data in view of the results of the analyses. Teaching an experimental design short course has the benefit that it assists not just one segment of the experimental station, but it cuts across all application areas on the experimental station.

**PRESENTATION OF SHORT COURSE ON THE USE OF THE SAS STATISTICAL COMPUTING PACKAGE**

On February 5-7, 2000 I presented a short course on the use of SAS (a well-known statistical package) for randomizing treatments to plots and for analyzing experimental data. This package was developed at the North Carolina State University for analyzing data of the North Carolina Agricultural Experiment Station and is very useful for analyzing agricultural and biological data from such an environment. It may also be used in analyzing data from sample surveys.

There was a great deal of interest in this topic on the part of the station researchers and staff and their attendance held up very well over the three day period. I don't expect many of them to have become proficient in the use of SAS during the three day period (except for one or two persons), but I consider it an opportunity to discuss some issues such as the importance of obtaining good reliable data, and the furtherance of the quantitative aspects of research. With continued emphasis on these themes from time to time, the quality of the research should improve. Examples used in the class were from a variety of experimental designs and experimental situations. Thus, it was a good opportunity to include some training in experimental design principles. One example, from the area of soil fertility, was supplied by a station researcher in the class and we used this as an example to show how the analysis might be carried out and then how the results might be interpreted. On the second and third days of the class, a projector was used to project the images from the screen of my notebook computer on to the wall so that the participants could get a good idea of the commands and the resulting output from the computer.

As more computers and copies of SAS become available, informal SAS short courses should be presented. However, this should follow a thorough grounding in experimental design principles and an introduction to variability patterns in data.

## PLANNING OF A SERIES OF EXPERIMENTS ON BANANAS AND PALMITO

On Monday, December 13, 1999, I assisted with the planning of a series of experiments on Banana and Palmito which need to be installed in the Chapare region in late 1999 or early 2000 and succeeding years. Others assisting in the planning were Dr. Larry Szott, Dr. Armando Ferrufino, Ing. Andres Quiroga and Ing. Walter Vargas. Our strategy was to design one replicated experiment within a watershed and then design a series of smaller demonstrational trials which include two of the same treatments which occur in the experiment. The number of watersheds for banana will be three. All design parameters within the series of locations of experiments should be constant. Also, all design parameters within the series of demonstrational trials should be constant. The demonstrational trials will not be replicated within a site due to the need for large plots and consequent large total area required. With only two treatments, if these demonstrational trials were to be elevated to replicated experiments, it would take more replications than could be handled on a farm. Consequently, if the proper number of replications cannot be achieved for a replicated experiment, the chances of enough power are so low that one should not invest the money in an undersized experiment because the power of the test would be so low.

For the BANANA EXPERIMENTS, 3 sites (each in a watershed) on low terraces. K experiment (with N at blanket level):

Treatments:

| | |
|---|---|
| 0 N | 0 K |
| 200 N | 0 K |
| 200 N | 400 K |
| 200 N | 800 K |
| 200 N | 0 K + removal of total biomass of banana |

Experimental Design: Randomized Complete Block with 5 blocks per location. Separate randomizations for each location.

Analyses: Soil and vegetation analyses before installation and at 1 or 2 years afterwards.

Plot Size: Each plot is 4 plants by 10 plants, 2.5 m between plants in both directions. Total of 845 $m^2$ per replication, giving a total experimental size of 4,225 $m^2$ per location.

Analysis of Variance for Experimental Data Per Site:

| Source | d. f. |
|---|---|
| Rep | 4 |
| Treat | 4 |
| Error | 16 |
| Total (corr.) | 24 |

Analysis of Variance for Combined Data Over Sites:

| Source | d. f. | |
|---|---|---|
| Loc | 2 | |
| Rep (Loc) | 12 | |
| Treat | 4 | Treatment should be tested by L x T mean square and |
| L x T | 8 | L x T should be tested by Pooled Error Mean Square |
| Pooled Error | 48 | |
| Total (corr.) | 74 | |

Design of Demonstration Trials

At each locations, 2 treatments for each plot (0 N - 0 K) , and (200 N - 400 K), non-replicated. Plot size should be ¼ ha. Locate the plots on homogeneous land and flip a coin as to which side the control treatment will be located. Approximately 25 farmer sites.

Analysis of Variance of Demonstration Trial Data:

| Source | d. f. |
|---|---|
| Loc | 24 |
| Treat | 1 |
| Error | 24 |
| Total (corr.) | 49 |

For PALMITO experiments, there will be more locations than the three in banana and at one of the sites, two different populations will be studied, but these will be separate experiments. In this case, N will be varied and K held constant. At the population of

5000 plants/ha, the treatments will be: 0 N 75 K; 100 N 75 K; and 200 N 75 K. Again, 5 replications of each plot; each plot is 80 $m^2$ and each rep being 320 $m^2$ in size. The dimensions of the plot will be 4 plants wide and 7 plants long. For the population of 10,000 plants/ha, the K levels will be 0, 100, 200, and 300 kg /ha. The plot sizes will be the same as those for the lower plant population. The analyses of variance will follow the same format as that given for bananas except the degrees of freedom will be different due to the larger number of treatments.

Criteria for Selecting Demonstration Trial Sites

Farms should be located on acid soils on high terraces and should represent the variability at each location. Avoid the extremes.

## RECOMMENDATIONS FOR PLANNING SERIES OF EXPERIMENTS ON OTHER CROPS

I would recommend using the same general format as recommended for the fertilizer trials on Bananas and Palmito for the experiments and trials on other crops. This amounts to a series of several well-designed replicated and randomized experiments serving as an anchor and then a series of demonstration trials having a more limited number of treatments which will have minimum replication. The treatments in the demonstration trials should be from the set used in the central experiments. Even on the demonstration trials, replication is desirable as it stabilizes the estimates and insures against a treatment falling upon favorable or unfavorable conditions and all of the information being projected from that one plot. Treatments for the demonstration trial should be such that the treatment result should be better than the control in nearly all cases, otherwise the farmer will be confused. Certainly after these first experiments and trials are completed, we should evaluate the results and see if changes in their design need to be made. The design phase should be dynamic depending upon precision results of existing experiments and trials.

IPM experiments are another situation. I would recommend using the network of trained extensionists and researchers to spot IPM problems in the fields and report them to IBTA staff. This is not an experimental step. It is an observational or case study approach. With enough of these observations, it is possible to generalize in which areas a problem exists and then sampling studies or experiments will need to be set up. These will vary in design according to the type of IPM problem. I would emphasize the observational step at this stage and to get the extension staff trained to diagnose problems in the field and the networking and reporting phases well-established before going into a massive sample survey or experimental phase in the field. IPM problems are localized and it really doesn't pay to spread scarce resources around without a disease or insect area focus.

**CONSULTING IN THE CHAPARE DURING SECOND PART OF CONSULTANCY IN BOLIVIA (February 2-10, 2000)**

My work in the Chapare was scheduled by Ing. Andres Quiroga, the current biometrician at the station. During the period indicated above, I worked with most of the researchers on the station. A detailed listing of the researchers with whom I met is given in the Appendix of the report under Calendar of Activities of Consultancy. Much of the time was spent in planning new experiments rather than in analyzing data. I left the recommendations for the design of each experiment and the appropriate analysis with the researcher involved. I came away with the feeling that researchers sometimes were insecure about whether the research that they were planning was relevant or not. In one entomological experiment, anticipated problems of interference among plots would not have been a problem if the researcher had diagnosed the problem better. His concern about interference of phermones from plot to plot would not have been a concern had he understood that these chemicals are specific to individual insect species and therefore one wouldn't be conducting an experiment involving a mixture of different pheramones.

The other observation was that there is a tendency to conduct small experiments or trials with limited numbers of replications and limited numbers of degrees of freedom available for estimation of experimental error. I can see the space problem, especially for the experiments which are conducted on farmers' fields. But somewhere in the research chain, full-fledged well-designed and replicated experiments need to be included. And this should probably be on the experiment station or on fields of farmers who are cooperating with the research staff of the research station.

## RECOMMENDATIONS

1) A more complete short course in principles of investigation and experimental design should be offered at the IBTA La Jota Station in late spring or early summer of 2000.

2) A network of trained extensionists and researchers should be established to spot IPM problems in the field and bring them to the attention of the research staff of the IBTA La Jota Station. The research staff should then seek outside help if necessary to tackle some of these problems (e.g. cirtus canker). This activity should be continuous because disease problems are very dynamic.

3) Two more copies of the SAS statistical package should be ordered for use on the La Jota Station.

4) Several experimental design and statistical methods books (in Spanish) should be ordered for the Biostatistics Department of the IBTA La Jota Station.

5) Researchers should take stock of their experiments, validation trials and demonstration trials to see if they are precise enough for their purposes. If they are not, more replication, more careful selection of the site, more careful selection of experimental material, and/or more careful control in the field will be necessary.

6) IBTA La Jota Station staff need to be drilled on the need to focus on quantitative aspects of research.

7) In addition to point 6, there should be more consideration of priorities of topics for research. These come from a review of literature as well as a thorough knowledge of the subject matter. Input from the network mentioned in 2 above should also be helpful.

8) Further informal SAS short courses should be offered at the La Jota Station.

# APPENDICES

# SCOPE OF WORK

SPECIALIST IN EXPERIMENTAL DESIGN

Proposed Personnel: Dr. Larry A. Nelson, Professor Emeritus of Statistics and Campus Coordinator of the CONCADE Project, North Carolina State University

Number of days: 10, 13

Period of Performance: December 5-14, 1999 and January 31-February 12, 2000

**Background/Justification**

A major emphasis of Critical Task c) under Special Objective 1 (Sustainable Farm Level Production Capacity of Licit Crops Established) of the CONCADE Project is to establish a massive program of applied on-farm research that can be used to generate needed information, validate technologies, serve as demonstrations for farmers, and increase farmer capacity by involving them in the research, validation, and technology adaptation processes. On-farm experiments can serve as valuable training for researchers, extension personnel, as well as for the farmers. It brings researchers and extension staff to the farms where they will become more familiar with the problems the farmers are facing and they will be able to make more specific recommendations. These experiments create a great deal of interest by the neighbors of the participating farmers and thus the extension effect is multiplied considerably.

On-farm experiments present a number of design challenges because of considerable variability in the site conditions, small farms, poorly controlled experimental technique, and limited numbers of treatments and replications. It is therefore necessary to engage the services of an experimental design expert to set out the design parameters and to train those who will be designing and implementing the experiments and analyzing the data

generated. The points in the experimental chain that are most critical from a variation standpoint need to be pointed out to those involved in on-farm trials so that special attention will be focussed on them in the experimental process.

**Objectives**

Assist the long-term expatriate team and newly hired Bolivian staff members and CONCADE partners to:

1) Design a number of on-farm experiments dealing with themes such as soil fertility, pest and disease control, plant spacing or population management, variety selection and adaptation, etc.

2) Train the above personnel in the principles of experimental design so that they will be able to design and implement similar experiments in the future; and

3) Train research personnel and data analysts in the appropriate statistical analyses and interpretation of the data.

**Tasks**

This short-term assignment is comprised of the following tasks:

Task 1: To discuss the objectives of various anticipated experiments to be conducted on farmers' fields in the Chapare region of Bolivia and to give suggestions as to how the objectives might be revised and/or better stated (if appropriate). These experiments will deal with areas such as soil fertility, pest and disease control, plant spacing or population management, variety selection and adaptation, and perhaps other themes of interest.

Task 2: To assist field researchers in various aspects of planning on-farm experiments with attention to such aspects as experimental design, treatment selection, numbers of

replications, randomization, plot size, location and arrangement of plots, and careful experimental and field plot technique.

Task 3: To discuss anticipated precision of on-farm experiments with field researchers in view of tasks 1 and 2 above.

Task 4: To assist those with the responsibility of analyzing experimental data for the Chapare region of Bolivia in the storage of data and the choice of statistical packages for the computer upon which the analyses will be run.

Task 5: To discuss the data analysis and interpretation phases of on-farm experiments with field researchers and statisticians who will be involved in such activities (logical contrasts, tests of significance, choice of error rate, measures of precision, combining data over locations, etc.).

Task 6: To collaborate with Bolivian scientists concerning needs for future statistical involvement by NCSU statisticians both in the area of design of experiments and in sample survey.

**Outputs and Deliverables**

Presentation of a three-day short course on the topic, *Use of the SAS Statistical Package.* Participants will be staff of IBTA, La Jota Station.

Presentation of a half-day seminar on the topic, *Improving Precision of Research Results Through Use of Statistics*. Participants will be staff of GOB research organizations or related institutions.

Written report in Spanish summarizing the steps in the design of each of the on-farm experimental series (one for each specific type of experimental application) and methods for analysis of the resulting data.

Reports will be written in English with notes and training materials in Spanish. All reports, notes and training materials will be due before departing Bolivia.

**Timeframe**

A proposed starting date is December 5, 1999. The consultant will be expected to spend 21 days in Bolivia, divided between the Chapare and Cochabamba.

## CALENDAR OF ACTIVITIES OF CONSULTANCY

Sunday, 5 December 1999

Travel from Raleigh, North Carolina to Cochabamba

Monday, 6 December 1999

Larry Szott; CONCADE Project discussions

Tuesday, 7 December 1999

Jose Infante; Administrative details, Imprest Account Banco Santa Cruz; Imprest Account CONCADE Comite de Implementacion meeting in USAID University of Cincinnati/Digital Earth Consulting Presentation and Discussions; Discussions with STTA Marco Vinicio Saenz

Wednesday, 8 December 1999

CONCADE Project Administrative discussions and follow-up actions; Travel to Villa Tunare, Chapare

Thursday, 9 December 1999

Dr. Rui Leite's seminar and discussions; Field visit to experimental site. Pineapple and palmito experiments.

Friday, 10 December 1999

STTA's, Maloney, Averre and Sorensen; Seminars and discussions at La Jota Station; Field visit to banana experiments.

Saturday, 11 December 1999

Field visit to black pepper experiment; Consultation with Dr. Rene Andrew

Sunday, 12 December 1999

Presentation of lecture on *Improving Precision of Research Results Through Use of Statistics*

Monday, 13 December 1999

CONCADE Project Administrative discussions and follow-up actions. Discussions with Larry Szott and Steve Huffstutlar

Tuesday, 14 December 1999

Travel to Raleigh, North Carolina

Monday, 31 January 2000

Travel from Raleigh, North Carolina to Cochabamba

Tuesday, 1 February 2000

Arrived Cochabamba at 3:00 PM. I had some discussion with Edmundo Ballivian about financial matters.

Wednesday, 2 February 2000

I had further discussions with Dr. Szott about the NCSU component of the CONCADE Project and with Charles Foster about the LOE for the fourth quarter of 1999 for the NCSU consultants and long-term staff. We made revisions in the NCSU portion due to confusion as to whether to report days or hours. I had further discussions with Mr. Ballivian and some with Jose Infante concerning DAI - NCSU financial arrangements. I left for the Chapare at 5:30 PM with Dr. Szott, Dr. Pedro Valdiviezo, and Mr. Roland Bunch. We arrived in the Chapare at approximately 9:00 PM.

Thursday, 3 February 2000

I consulted with Arturo Quispe concerning Black Pepper Experiments and Validation Trials.

Friday, 4 February 2000

I consulted with Mario Zenteno about sample surveys and topics related to Agricultural Economics. Also, I consulted with German Inturias on Palmito Agronomic Management. I consulted with Rolando Escobar concerning design of banana experiments and subsequent analysis of data.

Saturday, 5 February 2000

I consulted with a group of integrated pest management researchers for the entire day. These were: Dr. Rene Andrew, Entomologist; Ing. Gunter Marcus, Tecnico MIP; Ing. Carmen Calderon, Tecnico MIP - Fitopatolgia; Ing. Fernando Bohorquez, Tecnico MIP, and Ing. Andres Quiroga, Bioestadistica. We discussed a number of difficult, but important design issues.

Sunday, 6 February 2000

I taught the introductory portion of the three-day SAS course to 20 IBTA researchers.

Monday, 7 February 2000

I taught the second part of the three-day SAS course to the same researchers who were in the Sunday class and consulted with Jose Camacho and Carmen Calderon and Rene Andrew in the afternoon. This group of researchers wanted assistance on models and design of experiments in the diagnostic laboratory of diseases and insect infestations.

Tuesday, 8 February 2000

I taught the third part of the three-day SAS course in the morning and met with Dr. Armando Ferrufino in the afternoon. I also met with Raimundo Montano on maracuya and citrico investigations.

Wednesday, 9 February 2000

I consulted with Walter Varghas on models and design of soil fertility experiments and methods of sampling, and with Rosario Lucero on models and design of experiments in the Biotechnology Laboratory. Also I helped Benigno Ocampo and Vincente Equez analyze and interpret a set of plant disease data for bananas using the SAS package.

Thursday, 10 February 2000

I spent the early part of the morning continuing the consultancy with Rosario Lucero discussing the need for blocking for some experiments conducted in the Biotechnology Laboratory. We made an on-site visit to the lab for determining what sources might be causing excess variation in the laboratory and how blocking might be carried out operationally. In late morning, Mr. Roland Bunch, Dr. Frank Smith and I left for Cochabamba.

Friday, 11 February 2000

I spent the day preparing this report and having an exit interview with Mr. Steve Huffstutlar. Drs. Frank Smith and Larry Szott were also present at that meeting.

Saturday, 12 February 2000

I spent the entire day traveling to Raleigh, North Carolina.